National Aeronautics and Space Administration

September 25, 1998

NRA-98-OES-12

RESEARCH ANNOUNCEMENT

NEW MILLENNIUM PROGRAM MEASUREMENT CONCEPTS

Proposals Due November 24, 1998

OMB Approval No. 2700-0087

NEW MILLENNIUM PROGRAM MEASUREMENT CONCEPT
NASA Research Announcement
Soliciting Research Proposals
for
Period Ending
November 24, 1998

NRA 98-OES-12
Issued September 25, 1998

Office of Earth Science
National Aeronautics and Space Administration
Washington, DC 20546

OFFICE OF EARTH SCIENCE (OES)
NEW MILLENNIUM PROGRAM MEASUREMENT CONCEPT

The National Aeronautics and Space Administration (NASA) announces the solicitation of proposals for measurement concepts for its New Millennium Program in support of the Office of Earth Science (OES). The New Millennium Program (NMP) seeks proposals for measurement concepts leading to advanced payloads, which will be validated on future flights in support of OES technology development and scientific research.

I. Introduction

NMP is a technology program managed jointly by the NASA's Office of Space Science (OSS) and Office of Earth Science (OES). The program focuses on spaceflight validation of advanced technologies (i.e., instrumentation and operations) which offer the potential to accomplish the following:

- Reduce costs of future space and Earth science missions;
- Increase the quality and quantity of future science missions; and,
- Enable entirely new measurements and science, or new ways of accomplishing important previously attempted measurements from the environment of space.

Both *technology-push* and *science-pull* technologies are appropriate for consideration for NMP. While technology validation is the primary objective for NMP, its missions will conduct as much science as possible within the available parameters.

NMP missions for OSS are referred to as the Deep Space (DS) series. Its missions for OES are referred to as the Earth Orbiting (EO) series. This solicitation is for measurement concepts for the third EO mission.

Office of Earth Science

a. Objectives
The mission of the Office of Earth Science is to develop an understanding of the total Earth system and the effects of natural and human-induced changes on the global environment. In carrying out this mission, OES has identified as a key goal the need to expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft, and in-situ platforms.

Using the unique environment available with space platforms, NASA is observing, documenting and assessing large-scale environmental processes on Earth. Studies resulting from OES satellite data enable NASA to characterize and understand environmental change. This data also helps determine how human activities may have contributed to these changes and to understand the consequences of these changes.

The key technology strategy of OES is to implement its space flight program with smaller, lower-cost spacecraft and instruments that can be developed and launched within 2-3 years after selection of a target science measurement set, thus leading to greater program flexibility and robustness. A primary means of enabling this approach is to rapidly develop and validate advanced technologies that can enhance the capabilities while lowering the costs of future science missions. If these technologies require validation in space, this is the task of the New Millennium Program.

b. New Millennium Program

The goal of the NMP is to enable frequent, affordable, capable scientific missions in the 21st century by identifying, developing and flight validating key technologies which can significantly contribute to lowering life cycle costs and increasing scientific returns. Breakthrough technologies selected from the existing technology "pipeline"—which consists of the ongoing technology programs of NASA, other government agencies, industry and academia—will be developed in partnership with NMP. By validating critical technologies in space, NMP makes them available for future science missions at an acceptable level of risk, with the potential to have reduced development cycle times, and at lower overall cost. An additional goal of the NMP is to infuse advanced technologies into the U.S. Research and Development industrial base.

The primary objective of the NMP is to demonstrate and validate a suite of selected "leap ahead" advanced technologies that will aid NASA in realizing its vision for exciting, affordable science missions in the 21st century. To select these advanced technologies, the NMP has established six (6) Integrated Product Development Teams (IPDTs) which are responsible for identifying, developing, and delivering "breakthrough" technologies in the areas of autonomy, microelectronics systems, communications systems, modular and multifunctional systems, in-situ instruments and microelectromechanical systems, and instrument technologies and architectures.

This NASA Research Announcement (NRA) solicits advanced measurement concepts that are best suited for deployment in orbits other than the conventional Low Earth orbit. The selected concepts will eventually be developed into a full mission to validate a selected set of technologies. Responses to this NRA will be peer reviewed by a panel selected by OES. A peer review group will make recommendations to the Associate Administrator of OES who will serve as the selection official. Approximately three to four concepts will be chosen for a 6- month study, which will culminate in a complete mission implementation approach. One mission will be selected for future implementation (nominally a 33-month period) and a backup mission will also be identified. A Mission Confirmation Review will be conducted approximately 6 months into the mission refinement phase of the mission, and if the principal mission does not successfully pass this gate, the backup mission may be invoked. Figure 1 shows the Mission Definition Process that will be used for OES NMP technology validation missions.

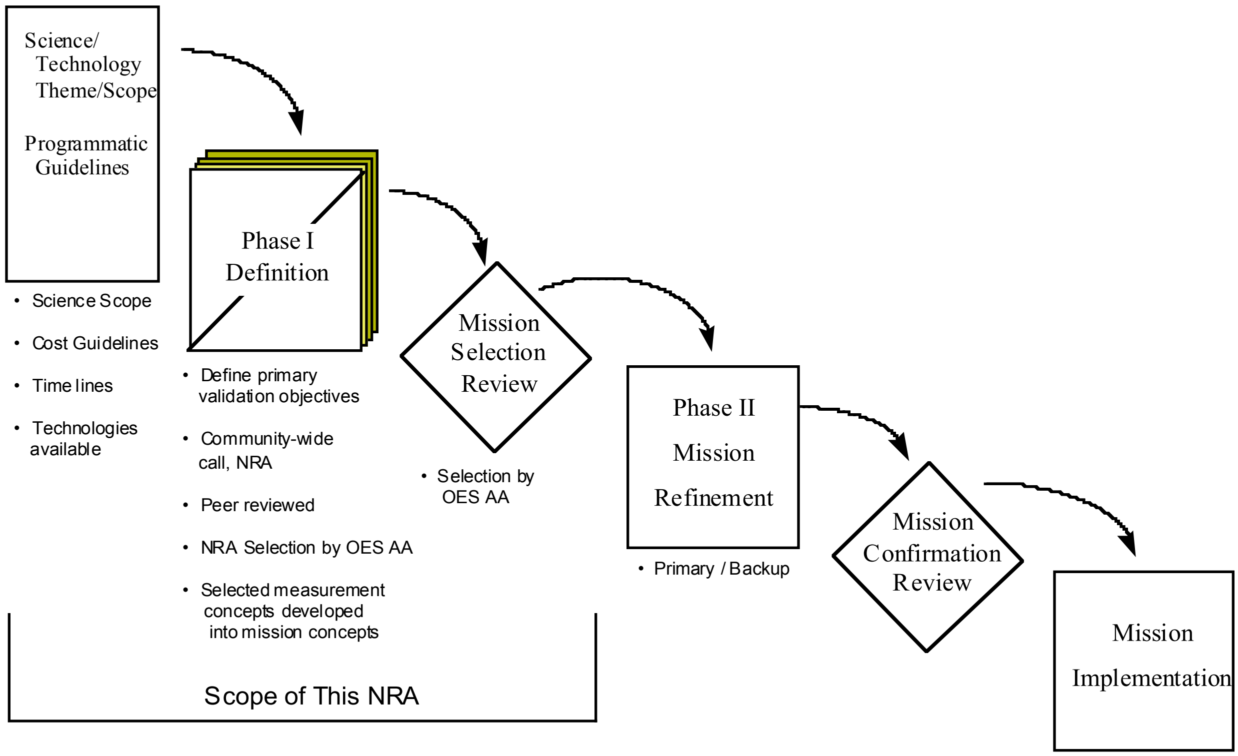

Figure 1 NMP Mission Selection Process

II. NASA Research Announcement

(a) Goals

This NASA Research Announcement solicits proposals for innovative measurement concepts, to be funded for the Definition Phase (Phase I in figure 1), that have the potential of evolving into instruments which can be validated in space on a New Millennium technology validation mission. In addition, the identification , and eventual validation, of advanced technologies that can be infused into the U.S. R&D technological base is an overarching consideration.

This NRA is open to any U.S. or non-U.S. organization including educational institutions, industry and nonprofit institutions. Non U.S. participation is subject to NASA policy (See Appendix F).

(b) Proposal Research Topics & Guidance

The primary emphasis of this solicitation is for measurement concepts that are best suited for orbits other than low-Earth orbits (which are defined as "quasi" circular orbits with apogee below 1000 km). This includes geosynchronous orbits, highly elliptical orbits, mid Earth and high-Earth orbits, and others such as monitors at L1 and L2. Measurement concepts proposed in response to this NRA can address any science discipline within OES that would benefit from observations acquired from these orbits. Proposals are specifically encouraged for measurement concepts addressing the following science disciplines:

Atmospheric Chemistry, including but not limited to super-regional pollution monitoring;

Atmospheric Climate and Water Cycle, including but not limited to measurements of temperature and moisture, winds from tracer drift, aerosols, clouds, radiation fluxes, precipitation, and mesoscale weather;

Ocean and Polar Science, including but not limited to ocean biology and physics;

Land Cover and Terrestrial Ecosystems, including but not limited to diurnal monitoring of land use, vegetative conditions, and fire occurrence and intensity;

Solid Earth and Natural Hazards, including but not limited to volcanic ash detection, severe storm tracking, and fire and flooding occurrences and intensity.

NMP is seeking advanced measurement concepts for which no capability currently exists, or that can provide breakthroughs in performance, or large (order of magnitude) reductions in mass, volume, cost, or resource use. This does not include measurement concepts that have already been planned as part of the OES Science Research Plan (September 1996). Because the NMP is a technology validation program, rather than a conventional science program, these measurement concepts must employ revolutionary technologies, and/or measurement strategies that will enable future science missions from orbits beyond LEO. These capabilities must be clearly defined in the proposal. Examples of such innovations include, but are not limited to, advanced imagers and sounders, systems requiring large deployable/inflatable apertures; coordinated multi-platform systems; advanced autonomous operation, and near real-time data downlink and distribution systems. To satisfy the requirements of this NRA, all proposed measurement concept must require a validation in space to reduce their risk to the first science users, and this requirement must be clearly justified in the proposal.

Possible approaches for flight validation include flights on free-flying satellites, either launched independently or co-manifested with other satellites and demonstrations on a non-New Millennium mission.

The NMP IPDTs have identified technologies that in part or as a whole may be applicable to the measurement concept being proposed. Appendix G lists candidate technologies that a proposer may desire to incorporate as part of their proposal. The technologies listed by the IPDTs have been competitively selected through an open process. If a proposer plans to use an IPDT technology, and the technology is eventually selected for flight validation, he/she must agree to use the previously qualified supplier.

(c) Phase IA Measurement Concept Definition

This NRA solicits proposals for highly innovative techniques for making space-based Earth remote sensing measurements. The NMP is chartered to validate in a space flight environment, advanced technologies from the entire national technology pipeline. Technologies that do not require space validation for their eventual scientific or operational use are not appropriate candidates for the NMP.

Successful proposers must present concepts that include a description of: 1) the system architecture, 2) the direct physical measurement made by the concept, 3) the basis for translating direct physical measurements into Earth science geophysical data, and 4) the technologies required in the system architecture. These concepts are expected to be at an appropriate level of maturity so that they can be demonstrated in space within 39 months from time of selection. This allows 6 months for mission concept definition (the activity solicited by this NRA), and a goal of 33 months for mission design and implementation. The proposals must be restricted to the approach of the measurement and should not include the details of a mission implementation other than any required to directly enable the measurement concept. The proposer must further identify how the proposed measurement concept can fulfill key Earth science objectives in future science missions, as well as what science, cost savings and other programmatic benefits this concept will provide. The proposer must describe the innovative nature of the measurement concept, including how the incorporation of "breakthrough" technologies will enable the concept. The breakthrough nature of the technologies must be discussed and the measurement improvements relative to currently available technology options must be described. The proposer must also provide a rationale for the requirement of space flight validation of the measurement concept and its associated technologies. The specific requirement for space validation, as opposed to validation that can be achieved through ground and /or airborne tests, must be described.
Up to four measurement concepts will be selected to enter into the mission definition phase.

(d) <u>Phase IB Mission Definition</u>
The successful proposers will become a member of a mission definition team. The Mission definition will be managed by a New Millennium Program Office - designated study lead from the Architecture Development Team (ADT). The ADT is led by mission architects from NASA and is responsible for the development of mission concepts for future validation missions. For the EO3 mission this team will be split into separate teams to address each successfully selected measurement concept. The role of the selected proposer will be to work with the team of mission designers and technologists to develop a documented mission concept, which will compete against two to three other mission concepts for selection as the EO3 mission. Specifically, the selected proposer will lead the team on all issues related to the demonstration of the measurement technique and participate in mission design trades and implementation planning. He/she will be responsible for defining (with the team): the approach , the required technologies, the validation plan, the scalability of the design to future applications, and the infusion path for the completely validated instrument.

Each mission concept team will work for 6 months to develop a documented mission concept, which will address the mission design, the mission implementation approach, and a complete cost estimate for implementation of the mission through the final technology validation. The deliverables from the study phase will include: 1) a documented mission design, 2) an implementation plan, 3) a formal cost estimate and 4) a risk assessment/management plan.

At the conclusion of the six month mission definition phase, the deliverables identified in the preceding paragraph will be evaluated by a peer review group. This group will present their results to the AA OES who will select one mission for implementation and one backup mission.

(e) Phase II Mission Refinement and Implementation

The New Millennium Program Office has the responsibility and authority of designing and implementing the technology validation missions. Project implementation authority is assigned by the program office with approval by the Office of Earth Science AA. In general, this assignment is made to a NASA Center or JPL, but consideration can be given to other organizations to take advantage of their unique expertise. The implementing organization designates a mission team, which is ultimately responsible for full mission implementation. The mission team is led by a project manager who will be assigned by the implementing organization. At this time the successful concept proposer may elect to continue his/her participation as a member of the mission implementation team. A brief description of the implementation approach for future missions is provided in Appendix H.

(f) Constraints

The cost of the 6-month study effort and the resultant deliverables has been budgeted as up to $1M (FY99$) per mission and as a guideline up to $250K, of the $1M, has been allocated for each successful proposer. The EO3 mission to be selected near the end of FY 1999, has been budgeted in the range of $60 to $70M, excluding launch vehicle. If there are costs associated with a piggyback or co-manifest, they are not part of the $60-$70M budget range. The goal of NMP is to have at least fifty percent of the mission cost, excluding launch vehicles, devoted to advanced technologies with $3 to $8M allocated for non-payload technologies (such as spacecraft bus, power, propulsion technologies, etc.).

(g) Relationship to Other Programs

Cross Enterprise Technology Development Program

The Advanced Technology and Mission Studies Division of NASA's Office of Space Science has chosen several field centers to help focus advanced, cross-cutting, component technology efforts. These centers establish and prioritize needs, negotiate with participating centers as well as industrial, university, and external agency partners to develop the required products, and to recommend funding.

Instrument Incubator Program

The objectives of the Instrument Incubator Program (IIP) are to identify, develop and (where appropriate) demonstrate new measurement technologies which reduce the risk, cost, size, and development time of Earth-observing instruments, and enable new Earth-observation measurements. The IIP is designed to bring instrument systems to a demonstrated technology readiness level consistent with successful science AO competition in today's fast track (3year) development environment. The Instrument Incubator will depend on NMP for space flight validation, if necessary, of instruments developed in the IIP which were selected during an open solicitation and peer review process.

(h) Performance Measurements
The output of the definition phase is a documented mission concept, with the deliverables enumerated in Section "d" above, which can be evaluated to determine if subsequent cycles in the project formulation phases and eventual future implementation should be undertaken.

(i) International participation
This announcement is open to the international science and technology community. International cooperative proposals, with team members from U.S. institutions participating in foreign-led proposals or with co-investigators from non-U.S. institutions on the teams of proposals from the U.S. institutions, will be accepted. These proposals should be on a "no-exchange-of-funds" basis for their non-U.S. elements and should identify any requirements for NASA financial support for U.S. participants. Proposals from non-U.S. institutions will be evaluated, but only on a "no-exchange-of-funds" basis. Specific instructions for proposals from non-U.S. institutions are included in Appendix F.

(j) Funding
The U.S. Government obligation to make awards is contingent upon the availability of appropriated funds, and the receipt of proposals, which are determined to be acceptable by the Government for award under this announcement. Contracts will be awarded as a result of this solicitation; grants, cooperative agreements or other funding arrangements will not be considered. Each contract will require delivery of a mission concept which addresses a mission design, the implementation approach for the mission and a complete cost estimate for implementation of the mission through the final technology validation and return of useful science data from space.

(k) Links
This announcement and appendices are available on the Office of Earth Science home page on the World Wide Web at http://www.hq.nasa.gov/office/ese/ (Look under "Research Announcement")

The complete text of the Science Research Plan is available on the World Wide Web at http://www.hq.nasa.gov/office/ese/draftsciplan/toc.htm

Information concerning the New Millennium Program including descriptions of each of the Integrated Product Development Teams can be found at:
http://nmp.jpl.nasa.gov/Participants/Teams.html

(l) Guidance to proposers:

Participation in this NRA or a subsequent similar NRA is not a prerequisite to being selected as a science investigator for any future OES Announcement of Opportunity(AO). Similarly, participation in this NRA does not guarantee continued participation in the mission or technology development for current or future NMP activities, except as described in paragraph (d), nor success in any future OES AO competition. Successful participation in this NRA is solely intended to give innovative measurement concepts the opportunity to mature to the point where they can be considered for future NMP technology validation missions. Solicitations similar to this announcement will be issued, in the future, to select additional measurement concepts that may evolve into future OES technology validation missions.

All prospective proposers are strongly encouraged to submit a letter of intent (see Appendix D) to propose to NASA in response to this announcement containing the information listed below. This letter will help to scope NASA's planning for the peer review process. The letter of intent may be submitted electronically through the Internet by completing the forms at URL: http://www.mtpe.hq.nasa.gov/LOI/form/html. Use the letter of intent forms if you do not have access to the Internet, and Fax a copy to 202-554-3024 with the following information:

NRA Identifier: NRA-98-OES-12
Title of Proposal
Proposers name, address, telephone number and FAX number
A brief summary of your proposal that includes the science area the measurement addresses (1 page)

Proposals should be prepared and submitted in accordance with the specific instructions provided in Appendices A-E of this Announcement. Appendix A provides specific instructions for proposers to this announcement. Appendix B contains general instructions needed for preparation of solicited proposals in response to NASA Research Announcements. Appendix C provides the list of certifications required and the sample cover sheet. All proposals submitted to NASA in response to this announcement must have a completed cover-sheet form and information on current and pending research support from all sources. Appendix E contains instructions for completing a one page budget summary for only the proposers costs. Appendix G contains lists of technologies that are available through the NMP Integrated Product Development Teams. If a proposer elects to use a technology that has been identified by an IPDT, they must agree to use the pre-selected developer/supplier of that technology. Appendix I contains a list of acronyms used.

Submit proposals to:

OES NMP-CS NRA
Code Y
400 Virginia Avenue
Suite 700
Washington, DC 20024
(For overnight delivery purposes only,
the recipient telephone number is 202-554-2775)

10 Paper copies and one 3.5" magnetic disk

Selecting Official: Associate Administrator, Office of Earth Science, NASA Headquarters

Point of Contact for Program Planning and Solicitation:

Lou Schuster
OES Code YF
NASA Headquarters
Washington, DC 20546-0001
Tel: 202-358-0772
Fax: 202-358-2769
lschuste@mail.hq.nasa.gov

(m) Selection Schedule

All proposals submitted in response to this announcement are due in accordance with the schedule below. Late proposals will not be considered for review and funding, unless it is judged to be in the best interest of the U.S. Government.

Draft NRA Release	August 21, 1998
NRA Release	September 25, 1998
Proposal Process and Technology Workshop	October 6, 1998
Letters of Intent to Propose Due	October 22, 1998
Proposals Due	November 24, 1998
Peer Review	November 1998- January 1999
Announcement of Selection	February 1999

Your interest in participating in this research opportunity is heartily welcomed.

ORIGINAL SIGNED BY

Ghassem R. Asrar
Associate Administrator for
Office of Earth Science

Enclosures:
Appendix A: Specific Guidelines for Proposers
Appendix B: Instructions for Responding to NASA Research Announcements
Appendix C: Sample Proposal Cover Sheet and Certifications
Appendix D: Letter of Intent
Appendix E: Budget Summary
Appendix F: Guidelines for International Proposals
Appendix G: Integrated Product Development Team Technologies
Appendix H: NMP Mission Implementation Approach
Appendix I: Acronym List

APPENDIX A

SPECIFIC GUIDELINES FOR PROPOSERS

The following evaluation factors will be used to evaluate the proposals, they replace and supersede those contained in Appendix B, paragraph (i) Evaluation Factors.

Criterion 1 Applicability to the NASA OES Science Measurements (60% of total value)

a. Evaluation of the proposal's relevance and the concept's potential contribution to NASA's scientific areas of emphasis. Is the concept a breakthrough, and are the technologies revolutionary?
b. The anticipated benefits of the proposed technique versus existing or currently planned sensors.
c. The potential of the measurement technique to evolve, once validated, into an operational instrument.
d. Does the concept enable a new measurement(s)?
e. The proposers documented plan for the infusion of the advanced technologies into the U.S. R&D industrial base.

Criterion 2 Maturity of the Concept (40% of total value)

a. Demonstration that the measurement concept payload is at an appropriate level of readiness that it can be delivered for integration onto a spacecraft or carrier by September 2001.
b. Justification as to why the instrument requires-on orbit flight validation.
c. Feasibility of obtaining the required measurement with the proposed concept.
d. Offeror's capabilities, related experience, techniques or unique combinations of these deemed to be integral factors for achieving the desire proposal objectives.

In addition to addressing the criteria and the requirements of sections (c) of Appendix B, each proposal must provide the following information which will not be scored:

- The role of the proposer as a member of the study team
- A cost estimate for the proposers effort associated with participation on the Phase IB study team. As a guideline, the proposers cost should not exceed $250K. The cost estimate should be completed on one sheet as per Appendix E.
- Proposers are also asked to provide their approach for measurement payload system development lead responsibility. The approach must be supported by a rationale that includes experience level and merits of the proposal. The payload responsibility approach may include but is not limited to the following: proposer's own institution may lead the effort; delegation of measurement payload to a NASA center or other government laboratory; a competitively selected industry developer. NASA will consider the proposed approach but is not committed to implement the approach proposed.

The section in Appendix B concerning length of the proposal is revised as follows:
The maximum length of each proposal should be limited to 10 non-reduced, single space, typewritten pages for the total description of the proposed measurement concept, management approach (role statement for study activities and approach to accomplishing the study) and facilities and equipment sections. This limitation does not include the cover sheet, the forms required by Appendix D, and the cost information sheet. Nor does it include the one-page summary sheet which must follow the cover sheet. Each proposal cover sheet must clearly indicate for which of the five science disciplines identified in paragraph II(b) it is being submitted. Each sheet of paper containing text, tables, or figures is considered a page.

Type font 10 point or larger must be used, and each page must have a minimum of one- inch margins. Paper must be white, standard 8.5 x 11 inch.

If the measurement concept is the result of a team effort, only 3 members of the team may be identified to participate in the follow-on study effort. Members proposed must have a unique and clearly defined role for the mission concept definition phase.

It is anticipated that the study team activities will take place at a NASA Center or JPL , unless the proposer can demonstrate that it is more cost effective to gather the team at a different location.

The proposer shall submit 10 paper copies and one 3 _" magnetic disk (Macintosh-or IBM PC-compatible format) with the proposal in Microsoft Word Version 7.0, or a comparable word processor format.

Since the government requires a mission concept as a deliverable, only contracts will be awarded as a result of this solicitation: no grants, cooperative agreements or other funding arrangements will be considered.

Appendix B

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS

(JANUARY 1997)

(a) General.

(1) Proposals received in response to a NASA Research Announcement (NRA) will be used only for evaluation purposes. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published for individual proposals.

(2) A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act.

(3) NRAs contain programmatic information and certain requirements which apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRAs.

(4) A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. NASA will determine the appropriate instrument. Contracts resulting from NRAs are subject to the Federal Acquisition Regulation and the NASA FAR. Supplement. Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NPG 5800.1).

(5) NASA does not have mandatory forms or formats for responses to NRAs; however, it is requested that proposals conform to the guidelines in these instructions. NASA may accept proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

(6) To be considered for award, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation.

(b) NRA-Specific Items. Several proposal submission items appear in the NRA itself: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information. Items included in these instructions may be supplemented by the NRA.

(c) The following information is needed to permit consideration in an objective manner. NRAs will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

(1) Transmittal Letter or Prefatory Material.

(i) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(ii) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(iii) Type of organization: e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(iv) Name and telephone number of the principal investigator and business personnel who may be contacted during evaluation or negotiation;

(v) Identification of other organizations that are currently evaluating a proposal for the same efforts;

(vi) Identification of the NRA, by number and title, to which the proposal is responding;

(vii) Dollar amount requested, desired starting date, and duration of project;

(viii) Date of submission; and

(ix) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

(2) **Restriction on Use and Disclosure of Proposal Information**. Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting an appropriate identification in the notice. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

Notice

Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

(3) **Abstract.** Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective and the method of approach.

(4) **Project Description**.

(i) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is discouraged.

(ii) When it is expected that the effort will require more than one year, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years.

(5) **Management Approach**. For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described.

(6) **Personnel**. The principal investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch of the principal investigator, a list of principal publications and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar

biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

(7) **Facilities and Equipment.**

(i) Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use. Include evidence of its availability and the cognizant Government points of contact.

(ii) Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

(8) **Proposed Costs.**

(i) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; consultants; subcontracts; other miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., principal investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all staffing data in terms of staff-months or fractions of full-time.

(ii) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self-evident. List estimated expenses as yearly requirements by major work phases.

(iii) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 1831 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).

(9) **Security**. Proposals should not contain security classified material. If the research requires access to or may generate security classified information, the submitter will be required to comply with Government security regulations.

(10) **Current Support**. For other current projects being conducted by the principal investigator, provide title of project, sponsoring agency, and ending date.

(11) **Special Matters.**

(i) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

(ii) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

(d) **Renewal Proposals**

(1) Renewal proposals for existing awards will be considered in the same manner as proposals for new endeavors. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

(2) NASA may renew an effort either through amendment of an existing contract or by a new award.

(e) **Length.** Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of "one-of-a-kind" attachments.

(f) **Joint Proposals**.

(1) Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

(2) Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or

equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

(g) **Late Proposals**. A proposal or modification received after the date or dates specified in an NRA may be considered if doing so is in the best interests of the Government.

(h) **Withdrawal.** Proposals may be withdrawn by the proposer at any time before award. Offerors are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

(i) **Evaluation Factors**

(1) Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's objectives, intrinsic merit, and cost.

(2) Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

(3) Evaluation of its intrinsic merit includes the consideration of the following factors of equal importance:

(i) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(ii) Offeror's capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(iii) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel critical in achieving the proposal objectives.

(iv) Overall standing among similar proposals and/or evaluation against the state-of-the-art.

(4) Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds.

(j) **Evaluation Techniques**. Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of-interest and protection of proposal information), such as by mail or through assembled panels. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, may be included in subsequent reviews unless the proposer requests otherwise.

(k) **Selection for Award**.

(1) When a proposal is not selected for award, the proposer will be notified. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a debriefing.

(2) When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation. The contracting officer may request certain business data and may forward a model award instrument and other information pertinent to negotiation.

(l) **Cancellation of NRA**. NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation.

Appendix C

Proposal Cover Sheet

NASA Research Announcement 98-OES-12
Proposal No. ______________________ (Leave Blank for NASA Use)

Title: ____

Principal Investigator::____

Department:____

Institution: ____

Street/PO Box: ____

City: _____________________ State: ___________ Zip: ____________________

Country: _________________ E-mail: ____

Telephone: ________________________ Fax: ___________________________________

Co-Investigators:

Name	Institution	Telephone
___________________	______________________________	_________________________
___________________	______________________________	_________________________
___________________	______________________________	_________________________

Budget:
1st Year: _________ 2nd Year: __________ 3rd Year: _________ Total: ____________

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in this *Cover Sheet/Proposal Summary* in response to this Research Announcement, the Authorizing Official of the proposing institution (or the individual proposer if there is no proposing institution) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications contained in this NRA [namely, (i*) Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs*, *and (ii) Certifications, Disclosures, And Assurances Regarding Lobbying and Debarment & Suspension*].

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Title of Authorizing Institutional Official: ____

Signature: _______________________________ Date: ____________________

Name of Proposing Institution: ____

Telephone: ________________ E-mail:____________________ Facsimile: _______________

Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs

The *(Institution, corporation, firm, or other organization on whose behalf this assurance is signed, hereinafter called "Applicant ")* hereby agrees that it will comply with Title VI of the Civil Rights Act of 1964 (P.L. 88-352), Title IX of the Education Amendments of 1962 (20 U.S.C. 1680 et seq.), Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. 794), and the Age Discrimination Act of 1975 (42 U.S.C. 16101 et seq.), and all requirements imposed by or pursuant to the Regulation of the National Aeronautics and Space Administration (14 CFR Part 1250) (hereinafter called "NASA") issued pursuant to these laws, to the end that in accordance with these laws and regulations, no person in the United States shall, on the basis of race, color, national origin, sex, handicapped condition, or age be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant receives federal financial assistance from NASA; and hereby give assurance that it will immediately take any measure necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of federal financial assistance extended to the Applicant by NASA, this assurance shall obligate the Applicant, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant for the period during which the federal financial assistance is extended to it by NASA.

this assurance is given in consideration of and for the purpose of obtaining any and all federal grants, loans, contracts, property, discounts, or other federal financial assistance extended after the date hereof to the Applicant by NASA, including installment payments after such date on account of applications for federal financial assistance which were approved before such date. The Applicant recognized and agrees that such federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign on behalf of the Applicant.

NASA FORM 1206

CERTIFICATIONS, DISCLOSURES, AND ASSURANCES REGARDING LOBBYING AND DEBARMENT & SUSPENSION

1. LOBBYING

As required by Section 1352, Title 31 of the U.S. Code, and implemented at 14 CFR Part 1271, as defined at 14 CFR Subparts 1271.110 and 1260.117, with each submission that initiates agency consideration of such applicant for award of a Federal contract, grant, or cooperative agreement exceeding $ 100,000, the applicant must **certify** that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit a Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

2. GOVERNMENTWIDE DEBARMENT AND SUSPENSION

As required by Executive Order 12549, and implemented at 14 CFR 1260.510, for prospective participants in primary covered transactions, as defined at 14 CFR Subparts 1265.510 and 1260.117—

(1) The prospective primary participant **certifies** to the best of its knowledge and belief, that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded by any Federal department or agency.

(b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (l)(b) of this certification; and

(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

Appendix D

Letter of Intent

All prospective proposers are strongly encouraged to submit a letter of intent in response to this announcement. This will allow us to alert a peer review staff to adequately cover the proposal review process. This letter of intent is available electronically via the Internet at URL: *http://www.mtpe.hq.nasa.gov/LOI/form.html***.** The URL for the Co-Investigator information is: *http://www.mtpe.hq.nasa.gov/LOI/coi.html*. We urge you to use these electronic letter of intent forms unless you do not have access to the Internet. In that case, we will accept a FAX copy sent to 202-554-3024 with the following information:

- PI and CoI names and addresses, (including Zip + 4);
- Title of proposal;
- Telephone number;
- Fax number;
- Email address; and
- A brief summary of what you plan to propose (Please limit this to no more than 3000 characters).

APPENDIX E

BUDGET SUMMARY

For period from ______________________ to __________________

- Provide a complete Budget Summary for year one and separate estimated for each subsequent year.
- Enter the proposed estimated costs in Column A (Columns B & C for NASA use only).
- Provide as attachments detailed computations of all estimates in each cost category with narratives as required to fully explain each proposed cost. See *Instructions For Budget Summary* on following page for details.

		NASA USE ONLY	
	A	**B**	**C**
1. Direct Labor (salaries, wages, and fringe benefits)	_________	_________	_________
2. Other Direct Costs:			
a. Subcontracts	_________	_________	_________
b. Consultants	_________	_________	_________
c. Equipment	_________	_________	_________
d. Supplies	_________	_________	_________
e. Travel	_________	_________	_________
f. Other	_________	_________	_________
3. Facilities and Administrative Costs	_________	_________	_________
4. Other Applicable Costs:	_________	_________	_________
5. SUBTOTAL--Estimated Costs	_________	_________	_________
6. Less Proposed Cost Sharing (if any)	_________	_________	_________
7. Carryover Funds (if any)			
a. Anticipated amount : ________			
b. Amount used to reduce budget	_________	_________	_________
8. Total Estimated Costs	_________	_________	XXXXXXX
9. APPROVED BUDGET	XXXXXX	XXXXXXX	_________

INSTRUCTIONS FOR BUDGET SUMMARY

1. Direct Labor (salaries, wages, and fringe benefits): Attachments should list the number and titles of personnel, amounts of time to be devoted to the grant, and rates of pay.

2. Other Direct Costs:
   a. Subcontracts: Attachments should describe the work to be subcontracted, estimated amount, recipient (if known), and the reason for subcontracting.
   b. Consultants: Identify consultants to be used, why they are necessary, the time they will spend on the project, and rates of pay (not to exceed the equivalent of the daily rate for Level IV of the Executive Schedule, exclusive of expenses and indirect costs).
   c. Equipment: List separately. Explain the need for items costing more than $5,000. Describe basis for estimated cost. General purpose equipment is not allowable as a direct cost unless specifically approved by the NASA Grant Officer. Any equipment purchase requested to be made as a direct charge under this award must include the equipment description, how it will be used in the conduct of the basic research proposed and why it cannot be purchased with indirect funds.
   d. Supplies: Provide general categories of needed supplies, the method of acquisition, and the estimated cost.
   e. Travel: Describe the purpose of the proposed travel in relation to the grant and provide the basis of estimate, including information on destination and number of travelers where known.
   f. Other: Enter the total of direct costs not covered by 2a through 2e. Attach an itemized list explaining the need for each item and the basis for the estimate.

3. Facilities and Administrative (F&A) Costs: Identify F&A cost rate(s) and base(s) as approved by the cognizant Federal agency, including the effective period of the rate. Provide the name, address, and telephone number of the Federal agency official having cognizance. If unapproved rates are used, explain why, and include the computational basis for the indirect expense pool and corresponding allocation base for each rate.

4. Other Applicable Costs: Enter total explaining the need for each item.

5. Subtotal-Estimated Costs: Enter the sum of items 1 through 4.

6. Less Proposed Cost Sharing (if any): Enter any amount proposed. If cost sharing is based on specific cost items, identify each item and amount in an attachment.

7. Carryover Funds (if any): Enter the dollar amount of any funds expected to be available for carryover from the prior budget period Identify how the funds will be used if they are not used to reduce the budget. NASA officials will decide whether to use all or part of the anticipated carryover to reduce the budget (not applicable to 2nd-year and subsequent-year budgets submitted for award of a multiple year award).

8. Total Estimated Costs: Enter the total after subtracting items 6 and 7b from item 5.

APPENDIX F

GUIDELINES FOR FOREIGN PARTICIPATION

NASA accepts proposals from entities located outside the U.S. in response to this NRA. Proposals from non-U.S. entities should not include a cost plan. Non-U.S. proposals, and U.S. Proposals that include non-U.S. participation, must be endorsed by the respective government agency or funding/sponsoring institution in the country from which the non-U.S. participant is proposing. Such endorsement should indicate the following points: (1) The proposal merits careful consideration by NASA; and (2) If the proposal is selected, sufficient funds will be made available by the sponsoring foreign agency to undertake the activity as proposed.

Proposals, along with the requested number of copies and Letter of Endorsement must be forwarded to NASA in time to arrive before the deadline established for this NRA. In addition, one copy of each of these documents should be sent to:

NASA Headquarters
Office of External Relations
Earth Science Division, Code IY
Washington, DC 20546
USA

Any materials sent by courier or express mail should include the street address 300 E Street, S. W., and substitute 20024 for the indicated ZIP code.

All proposals must be typewritten in English. All non-U.S. proposals will undergo the same evaluation and selection process as those originating in the U.S. Non-U.S. proposals and U. S. Proposals that include non-U.S. participation, must follow all other guidelines and requirements described in this NRA. Sponsoring non-U.S. agencies may, in exceptional situations, forward a proposal without endorsement to the above address, if review and endorsement are not possible before the announced closing date. In such cases, however, NASA's Earth Science Division of the Office of External Relations should be advised when a decision on the endorsement is to be expected.

Successful and unsuccessful proposers will be contacted directly by the NASA Program Office coordinating the NRA. Copies of these letters will be sent to the sponsoring government agency.

Appendix G

INTEGRATED PRODUCT DEVELOPMENT TEAM CANDIDATE TECHNOLOGIES

The below list is a subset of the IPDT technologies which are most likely to be relevant for this measurement concept NRA. Other IPDT mission technologies could be considered for incorporation during the mission definition phase. Those items marked with an asterisk (*) have been manifested on a New Millennium technology validation flight.

AUTONOMY TECHNOLOGIES

- FORMATION FLYING AND VIRTUAL PLATFORMS*

Offering the potential for revolutionizing the manner in which we conceptualize, plan, design, implement, and operate missions, Formation Flying and Virtual Platform techniques have been identified as key enabling technologies by the NASA Earth and Space Sciences Enterprises for the next generation Earth and Space Sciences campaigns. These technologies, allowing a distributed network of individual autonomous vehicles to act collaboratively as a single collective unit exhibiting a common system wide capability, will usher in a new era in Earth and Space science. Extensive co-observing campaigns, coordinated multi-point observing programs, significant improvements in space-based interferometry, and entirely new approaches to conducting Earth and Space science will be achievable while drastically reducing the complexities, limitations, costs, and schedule requirements associated with traditional science and mission concepts.

With the formation flying experiment being conducted on the New Millennium Program EO-1 mission, a significant step towards the realization and application of these technologies to Earth observing missions will be accomplished. The EO-1 spacecraft will conduct a co-observing program by flying in formation with the Landsat-7 spacecraft, maintaining a 1 minute +/- 3 second along track separation with Landsat-7. This experiment, during which 4 independent maneuver planning and execution algorithms will be evaluated, will demonstrate the ability to autonomously determine if and when maneuvers will be required, plan the maneuvers required, and execute these maneuvers.

Several major technological challenges remain to be overcome before the benefits offered by formation flying and virtual platform techniques can be fully realized. Current activities are focusing on the development of technologies to extend beyond simple 2-spacecraft coplanar configurations and to enable higher levels of autonomy and cooperation within the fleet of spacecraft. Among the critical technology elements now being addressed are the development of inter-spacecraft communication approaches and systems, relative navigation techniques and sensing devices, and formation flying and virtual platforms architectures, strategies, and control approaches.

- SCIENTIFIC FEATURE EXTRACTION

Allows for on-board science data detection and editing by the orbiting spacecraft. Maximizes bandwidth between space and ground by identifying and downlinking significant events such as storms, clear view of ground, earthquakes and volcanic dust plumes.

Automated onboard cloud-editing is the process of systematically identifying satellite image areas covered by substantial cloud formations. This process enables rapid editing and prioritization of image areas to be selected for downlink. The immediate benefit is that operations costs are reduced dramatically. This reduction is achieved by replacing time-consuming, tedious and expensive manual ground-based tasks with a lower cost and rapid automated procedure. This procedure allows the portions of an image or image sequence that contain clearly valuable scientific features to be flagged and downloaded quickly with highest priority at full resolution. This substantially increases the volume of useful scientific data returned to earth, without compromising resolution.

Onboard scientific feature and event extraction broadens this concept to capture a wide range of important (static) scientific features, as well as dynamic processes such as dust storms, cyclones, oceanographic currents and tectonic plate motions. This enables new types of scientific missions to be executed autonomously and cheaply, by enabling rapid autonomous satellite response to important scientific events that are flagged as candidates for imaging at higher resolution.

- ONBOARD ENGINEERING DATA SUMMARIZATION*

The onboard data summarization software available for EO3 will be an enhanced version of the flight software that is being developed and flown on DS1 as part of the Beacon Monitor Operations Experiment. Onboard summarization results in more concise downlinked telemetry without sacrificing the ability to perform critical data analysis. The primary advantages of this software are reduced operations cost and decreased mission risk because mission data analysis will be performed more efficiently and data logging and processing functions on the ground will be reduced since less data will be downlinked over the life of the mission. Data summarization software consists of several algorithms for storing the most important information at high resolution and nominal or "collaborating" sensor data at lower resolution. There are four main components to a summary: Top-level statistics, Episodes, Snapshot Telemetry, and Performance Data. A ground software tool, also developed for DS1, provides a visualization environment for interacting with the summary data once it has been downlinked.
Two of the software modules that generate summary data can also be used to improve the ability to perform onboard event or anomaly detection. One such module computes various transforms of engineering data using empirical or model-based techniques. A second software module implements the ELMER (Envelope Learning and Monitoring using Error Relaxation) technology developed at JPL for learning more precise alarm limits via a neural network (either onboard or on the ground). Using these adaptive alarm limit functions onboard can result in more precise

episode or anomaly identification, leading to fewer false alarms and faster identification of important time-critical onboard events.

Enhancements possible for E03 also involve tailoring summarization algorithms to detect important science events in order to facilitate quick interaction. Utilizing the software in this way can result in additional operations cost savings and possibly improve ability to plan follow-up science activities more effectively, increasing overall science data return.

There are many implementation options. Summarization can be applied to all or only a subset of engineering data channels, summary techniques can be selected or deselected for a given mission, the summarization system can be switched OFF as necessary in favor of bulk (normal) telemetry, and can be upgraded or enhanced as the mission progresses. Maintenance of the software, including periodic updates, can be easily implemented by modifying onboard configuration tables. If it is not possible to fly the summary software onboard, it can also be used on the ground to achieve significant mission cost savings.

- SCIENCE FROM A LAPTOP

A data-communication and processing network of compact, laptop-computer-based portable station communicating via the World Wide Web (WWW) has been proposed as a relatively inexpensive end-to-end ground support system for EO3. At present, end-to-end ground support functions (receiving, tracking, telemetry, command, monitoring, and control) are distributed among several subsystems in rack-mounted chassis. Many of these subsystems have outdated designs that entail high reproduction, maintenance, and operational (labor) costs. The costs are even higher than they might otherwise be because some functions are duplicated by two independent systems at the Deep Space Communications Complex (DSCC) and the Advanced Multi-Mission Operation System (AMMOS). The AMMOS is an intermediate product of evolution toward the proposed system and is not an end-to-end system; in the AMMOS, some telemetric and interfacial functions are implemented in software on a laptop computer, at data rates that are too low for typical spacecraft missions.

In the proposed system, only the antenna subsystems, central command subsystems, receivers, transmitters, and data-storage or buffering equipment would be retained at the DSCC. The other subsystems and the duplication between the DSCC and the AMMOS would be eliminated. Functions of tracking, ranging, command, monitoring and control, simulation and processing of telemetric data, central processing of data, and operation of the network would be performed by combinations of hardware and software in the portable stations.

To keep costs low, the portable stations would be made of commercial off-the-shelf products to the extent possible. To achieve the required data rates and promote modularity and interoperability, separate subsystem functions (e.g., telemetry, tracking, ranging, and command) would be implement in hardware on separate circuit cards that conform to the Personal Computer Memory Card International Association (PCMCIA) standard. The sizes of integrated circuits on the PCMCIA would be reduced by use of multichip-module (MCM) packaging techniques.

A portable station could be operated at any suitable location in the world; for example, at the DSCC, aboard a vessel, at a field site on land, or in a researcher's office or laboratory at a university. The system would enable a scientist to perform multiple tasks simultaneously from such a location. For example, a scientist could perform a sea-floor geodesy experiment by use of the Global Positioning System while tracking a spacecraft and processing telemetric data. Inasmuch as only one operator (the scientist or an assistant) would be able to manage all of these tasks, the cost of operating the system would be less than that of operating the present system, which depends on multiple operators.

The portable ground system will promote the New Millennium “on-call” operator concept by incorporating an easy-to-use, point-and-click, web-liked Graphical User Interface (GUI). The GUI eliminates the need for user programming. Thus, the Principal Investigator (PI) can be the operator of the future and dramatically reduce mission support cost. This work will be publish on the July issue of NASA Tech Brief.

COMMUNICATIONS TECHNOLOGIES

- HIGH-RATE OPTICAL DOWNLINK TERMINAL

The optical communications flight terminal is based on the Optical Communications Demonstrator (OCD) design. The OCD is a NASA/JPL-patented design that uses a single 2-dimensional focal-plane array detector and a single 2-dimensional fine-steering mirror to accomplish all the spatial beam control functions required to point a narrow optical beam back to an intended ground receiver. The design is based at present on a 10 cm diameter common (shared for beacon reception and return-beam transmission) telescope aperture with internal stray-light baffling. The terminal is capable of returning 500-1000 Mbps (or more) from Earth-orbital distances when received by a 1-m ground receiver telescope. The terminal will be used to transmit both PN-coded test pattern data, as well as high-rate S/C sensor data, to the ground site terminal.

- HIGH PERFORMANCE DATA COMPRESSION (HPDC)

The HPDC is a data compression algorithm designed specifically for science instrument space applications. It can operate on input data sample sizes from 8 to 16 bits/pixel with data rates up to 20M samples/sec. The algorithm, similar to a wavelet algorithm, uses a multiplexing lap transform in one dimension and a discrete cosine transform in the other dimension so as to provide excellent image quality while constraining error propagation. Its performance far exceeds current JPEG algorithms currently used commercially. The advantages over JPEG are the variable input sample size (JPEG fixed to 8 bits/sample) and does not require Hoffmann Code tables for the entropy encoder.

- HIGH RATE CHANNEL CODING

Use of the (64,40,8) sub-code of the Third-Order Reed-Muller (RM) code for high speed satellite communications: The RM subcode can be used either alone or as an inner code of a concatenated coding system with the (255,223) Reed-Solomon (RS) code as the outer code to achieve higher performance. The current rate 1/2, constraint length 7 convolutional decoder speed is limited to 40 Mbps as a result of its irregular Trellis structure. For example, for TDRSS users to operate at 150 Mbps, 16 decoders working in parallel are required which affects performance. The RM (64,40) subcode has a Trellis that is highly structured and requires the least decoding complexity with the potential to achieve a decoding speed of 600 Mbits/sec.

- Ka-BAND SOLID STATE POWER AMPLIFIER

A solid state power amplifier to provide transmitter function at Ka-band (32 GHz) with output rf power 5 Watts and an efficiency of 35-40 %. Build on the development of the 2.5 W amplifier at 32 GHz for NMP flight DS-1 and the 20W high efficiency X-band SSPA technology development of the Mars program. The innovation provided by this technology is that it uses high efficiency Gallium Arsenide rf devices and high efficiency circuit and packaging technology developed at both JPL and Lockheed-Martin.

- DEPLOYABLE - REFLECTARRAY ANTENNA

The purpose of this technology is to provide for moderately large aperture, high gain antennas (1.0 -3.0 m) in a low stowed volume suitable for launch within small shroud envelopes. The antenna provided is a High Gain Antenna with dual frequency (X-band and Ka-band) operation. It provides X-band up and downlink, and Ka-band downlink only with electronic beam scanning capability. The innovation presented by this technology consists of Flat panels with conducting patch elements that can be folded during launch and deployed to realize a low profile high gain antenna. The antenna can also be deployed by an inflatable mechanism where the patch elements are etched on thin membrane material. An inflated flat structure of the reflectarray is easier to maintain than an inflated curved parabolic structure. The RF feed is also deployed to irradiate the passive patch elements. Arrangement of feed can be designed for either an on-axis or off-axis feed arrangement. For a 1.5meter diameter antenna, the mass is comparable to a solid graphite composite parabolic antenna (3.3kg), but the ratio of deployed to stowed volume is now greater than a factor of two.

MICROELECTRONICS TECHNOLOGIES

- ADVANCED MICROCONTROLLER*

The Advanced Microcontroller (AMC) is the world's smallest space-qualified, self-contained computer with analog interface capability. The AMC has modest amounts of computing power (about the equivalent of an old Apple II computer), but achieves this capability in the size of a postage stamp (0.8" x 1.2"), the mass of a few potato chips (3 grams), and 1/20th watt of electrical power. The AMC possesses built-in instrumentation capability: six serial communications ports, 32 digital discrete lines, an additional 32 analog input lines, and eight presettable analog outputs. The AMC runs off its own internal clocks (either 10 MHz or 200 Hz for ultra-low power) or an externally provided time reference. Another feature of the AMC is its reconfigurable programming. Unlike many other computers, the AMC can be reprogrammed up until final integration, under electrical control; no de-integration is required. The AMC can also save data to its non-volatile memory, giving the AMC enough "smarts" to finish a task when interrupted by power removal.

- Spaceborne Fiber Optic Data Bus (SFODB)

The SFODB is a standardized, gigabit per second, highly reliable, fault tolerant fiber optic network. The fiber optic cable consists of 100/140 micron, multimode graded index fiber. SFODB was designed for the harsh space environments and real-time, on-board data handling applications of high speed, remote sensing spacecraft. The SFODB's one gigabit per second data transfer rate represents a thousand-fold data rate increase over the flight proven 1773 fiber optic protocol. The IEEE P1393 SFODB implements a doubly redundant, ring-based architecture which includes one controller node and up to 127 transmit/receive nodes. SFODB's low mass, low power, and reliable, high speed data transfer rate makes it well-suited for hyperspectral imaging and other high speed applications. SFODB was designed to support bit error rates less than 10^{-11} for non-solar flare and 10^{-9} for a maximum solar flare. Its software configurable Asynchronous Transfer Mode (ATM) based protocol provides users extraordinary flexibility when designing their data handling architectures.

SFODB's attributes combine to significantly reduce spacecraft development time and cost. The interaction of SFODB's high performance, new technology components in the space radiation environment requires flight validation. Ground testing and evaluation of the SFODB will be completed in 1999, and a flight-ready unit will be ready by late 2000.

IN-SITU INSTRUMENTS AND MEMS TECHNOLOGIES

- HIGH-SENSITIVITY, LOW-POWER, LOW-COST, SOLID-STATE RADIATION MONITOR

The ability to accurately detect and measure radiation, such as protons, neutrons, heavy ions, etc., in the natural environment of space is critical to the health of spacecraft electronics systems. Traditional equipment for detecting and monitoring radiation is bulky, consumes relatively large amounts of power, and is sometime sensitive to shock and vibration. This device is small, light-weight, accurate solid-state radiation monitor is a custom-designed Static Random Access CMOS Memory that upsets when struck by high energy particles such as protons, alpha particles, or heavy ions. Neutrons are detected by coating the detector with boron which generates alpha particles during a particle strike. The CMOS chip is 2.6 mm x 3.4 mm and requires 50 mW operating power.

For EO3 it is proposed to fly an 8 k-bit boron-coated SRAM and an 8 k-bit unboron-coated SRAM. This pair of SRAMs will allow the detection of both alphas, protons, and neutrons. The upsets of this detector will be compared to predicted and measured upsets in the electronics associated with the other instruments and control systems.

- MEMS-BASED XYLOPHONE MAGNETOMETER

MEMS-based xylophone magnetometer uses an alternating current to drive a micro-machined bar at its resonant frequency. The magnitude of the bar's deflection is based on the Lorentz force produced by the current and magnetic field, which is detected optically. This device can measure local magnetic field gradients as well as spacecraft magnetic interference. This MEMS magnetometer has a linear response. By altering the drive current, the sensitivity can range from nT to T. Its dynamic range far exceeds the fluxgate magnetometer, is much smaller, and uses much less power. Piezoresistive, magnetorestrictive magnetometers, and tunnel-based magnetometers have mT to μT sensitivities. The mass of the device is 10 g, it consumes 200 mW and requires < 1 cm^3.

For EO3, it is proposed to mount the magnetometer on the periphery of the spacecraft where it can sense magnetic fields in the 1 to 25 nT range. This will allow the demonstration of the sensitivity of the magnetometer to both the space environment and to the magnetic fields produced by the spacecraft itself. The readiness has been demonstrated by the successful operation of a breadboard and will be demonstrated by a brassboard version to be flown on APEX sounding rocket in Jan 1999. The MEMS version with optical sensing will be ready by late 2000.

- MEMS MICROGYROSCOPE

When fully developed the MEMS microgyroscope will provide the inertial reference for a spacecraft. This MEMS device is fabricated using bulk micromachining where the device has four pedals coupled to a central post that precesses in response to Coriolis force that changes the pedal capacitance. The device weighs < 1 gm, requires < 1 cm3, consumes < 0.5 W, and has infinite life due to no wearing parts.

For EO3, it is proposed to fly a three-axis version. The predicted capability is between 1 and 10°/hr. Its readiness is demonstrated by a breadboard version that will fly on a high-altitude aircraft in 1999. The EO3 device will be ready by late 2000.

- MEMS MICROACCELEROMETER

The MEMS micro-accelerometer is fabricated in silicon using micromachining processes. It uses a capacitance transducer and electrostatic force feedback to restrain the proof mass. The device does not require leveling and can operate in zero gravity. Its sensitivity is between 0.01 to 100 Hz with 2 ng/√Hz sensitivity, size is 2.5 x 2.5 x 2.0 cm^3, power is 200 mW at ±5 V, and weighs 50 g.

For EO3, it is proposed to flight validate the accelerometer's performance by detecting spacecraft motion. The readiness is seen in the various terrestrial field trials. A flight version, with the above capability, will be ready for EO3 by late 2000.

MODULAR AND MULTIFUNCTIONAL STRUCTURES TECHNOLOGIES

- HIGH-DISPLACEMENT PIEZOELECTRIC ACTUATORS

Piezoelectric actuators offer several advantages over conventional electromechanical devices for the precision positioning of instrument optics and for instrument pointing. Piezoelectric actuators are lighter weight, use less power, and are more reliable than electric motors. Piezoelectric actuators can enable compact instrument architectures.

A high-displacement piezoelectric actuator known as THUNDER has been developed and demonstrated in a variety of prototype remote sensing instrument applications. THUNDER actuators have the following characteristics:

Displacement:	~0.25 inches
Force:	~5 lbs
Power:	~1 W
Operating Voltage:	400 V
Fatigue Life:	> 1 million cycles

A THUNDER actuator is fabricated by bonding a piezoelectric ceramic to a flexible steel substrate. When a voltage is applied to the piezoelectric ceramic, it will expand or contract, depending on the polarity of the voltage. The deformations of the ceramic are amplified by bending in the flexible steel substrate to generate relatively large displacements. By stacking several actuators in series, displacements on the order of 1-2 centimeters have been demonstrated.

THUNDER actuators have been successfully incorporated into prototype instruments. A 2-axis gimbal mechanism using piezoelectric actuators has been demonstrated for pointing of a solar occultation spectrometer. The actuators move the spectrometer through a range of +/- 5 degrees. A linear THUNDER motor has also been developed for rapid translation of a scan mirror in a Fourier Transform Spectrometer. Piezoelectric actuators can be used for controlling the shape of lightweight, flexible telescope mirrors. Actuators that can operate at cryogenic temperatures (30 ^{o}K) with position-hold capability are currently being developed for the Next Generation Space Telescope.

- LITHIUM-ION BATTERY

For space probe and satellite energy storage needs, lithium-ion (Li-ion) batteries offer a low-cost, low-weight, small size alternative to the state-of-the art nickel-cadmium (Ni-Cd) and nickel-hydrogen (Ni-H2) cells that are currently used for such applications. With energy density (Wh/l) and specific energy (Wh/Kg) ratings that are 2-4 times that of these current systems and a much better charge retention and charge efficiency, they will significantly reduce launch vehicle and solar array costs. Li-ion cells have demonstrated the capability of providing >1000 full depth of discharge (DOD) cycles and are expected to support a calendar life of more than 10 years. Consequently, their use will be especially advantageous for both deep space missions and earth orbiting missions located in geosynchronous earth orbit (GEO). The Li-ion battery cycle life was recently extended to the 10,000 cycle domain by limiting charge voltage.

- PULSED PLASMA THRUSTER SYSTEM*

The Pulsed Plasma Thruster (PPT) system is a compact, totally self-contained propulsion system capable of micro-Newton-second impulse bit precision spacecraft control. The PPT employs solid Teflon as a propellant and requires only 28V power leads, 5 analog command lines, and a mechanical hardpoint for mounting. The envelope of a PPT with 2 axis thrust capability is only approximately 5300 cm^3, including propellant. It can produce variable thrust depending on firing frequency up to approx. 2 milli-Newtons. Its Isp of 1000 - 1200 sec makes it attractive for missions which require a larger amount of delta V than feasible with cold gas systems. Because there are no moving parts, the use of PPTs for spacecraft ACS can result in a much lower jitter environment than reaction wheels. PPT systems capable of approx. 15,000 N-s are now being developed.

- COMPOSITE SILICON CARBIDE OPTICAL BENCHES/CRITICAL STRUCTURES

The excellent mechanical and thermal properties of silicon carbide (SiC) optical components have been shown to enable very lightweight and thermally insensitive optical assemblies. Small aperture instruments at <10kg and visible-level optical performance over a 200C thermal range with significant gradient conditions have been demonstrated. These characteristics are critical for GEO-mission payloads given the high cost of orbital insertion and significant thermal gradient conditions caused by partial solar illumination. However, the large aperture requirements of a typical GEO mission dictate the need for a more robust, thermally-matched optical bench material for the SiC optical components.

A SiC/SiC material made from different forms of silicon carbide satisfies these requirements. The composite is inherently stable thermally; is not hygroscopic; does not have a moisture expansion problem; and thermally matches optical SiC forms over all temperature ranges without the need for CTE tuning. In addition, the material has a 5x fracture toughness improvement over the ceramic forms; can be machined (including core drilling); and can be configured into large sizes and complex shapes.

To date, ground-based hardware demonstrations using this composite material have included monococque optical benches for visible-quality telescopes; truss structure designs; and centrallysupported pedestal configurations for large aperture IR spectrometers. This technology is now ready for on-orbit demonstration of passively athermal optical systems or other precision structural elements such as deployables..

- PRECISION DEPLOYABLE STRUCTURES AND MECHANISMS

The University of Colorado, working closely with NASA Langley and with NASA JPL for several years, has developed and helped to develop several concepts and components for deployment of microdynamically stable, lightweight, large precision apertures. These include:

- Deployable telescope with 1-2 micron absolute shape accuracy (good for LIDAR instruments or diffraction limited IR) and sub-micron level microdynamic stability. Associated panel technology includes 10 kg/m^2 for optical and 2-5 kg/m^2 for high frequency RF applications.

- High precision (sub-micron hysteresis), low friction revolute joints for deployable mechanisms and microdynamically stable structures

- High precision, low hysteresis (nanostrain level) latches for deployable mechanisms and microdynamically stable structures

The possible EO3 instruments impacted by this technology include:

Deployable LIDAR telescopes
Deployable filled aperture optical telescopes
Deployable sparse aperture optical imagers
Deployable high frequency RF antennas

- MULTIFUNCTIONAL STRUCTURES (MFS) TECHNOLOGY FOR CABLELESS SPACECRAFT*

This MFS technology offers a modular architecture by directly incorporating electronic subsystems (i.e., data transmission and power distribution network, representative C&DH subsystem and power control subsystem), on a structural panel with integral thermal control. In so doing, it eliminates the need for bulky cables, connectors and chassis used in conventional spacecraft. Further, it allows a 75% increase in flight system payload mass, order of magnitude reduction in flight system development costs and frees up internal spacecraft volume.

This is implemented by incorporating recent advances in microelectronics, thermal control, and structures and materials. Specifically, the data transmission and power distribution network is constructed on thin multilayer Cu/PI circuit patches that are adhesively bonded onto the structural panel with integral thermal control. The MCMs (2D or 3D) performing specific functions (e.g., C&DH or power conditioning) are mounted directly on the structural panel via an interface pad. The circuit patch basically eliminates cables and harnesses by using etched-in copper conductor lines in its multilayer architecture. The direct mounting of MCMs with formed shielding covers further eliminates the need of large enclosures and circuit boards.

With the successful development and demonstration of the MFS panels in an AFRL/DARPA/BMDO and internally funded program, Lockheed Martin is designing and fabricating the MFS panels for the following demonstration experiments:

- ♦ MFS Panel Experiment on Deep Space1 (DS1)
- ♦ Flex Tether and interconnect on DS2.
- ♦ MFS Flight Panel for BMDO's Spacecraft Technology Research Vehicle (STRV) 1d.

- LARGE PRECISION INFLATABLE ANTENNA, SAR, SOLAR ARRAY, AND/OR BOOMS FOR GEO REMOTE SENSING, COMMUNICATIONS, POWER, AND/OR STRUCTURE.

Inflatables offer significant potential savings over equivalent mechanically deployed systems. These saving are on the order of: 10X less cost, 10X less packaging volume and 2-5X lighter. Inflatables have been shown to be almost critically damped, with good thermal stability, given proper tailoring of optical properties, due to the high radiative transfer rate. In many cases they can provide dual functions, such as a communication antenna that at the same time serves as a solar concentrator to provide spacecraft power, with further savings in spacecraft weight, launch volume and overall cost.

Inflatable antennas:
L'Garde has built apertures up to 14m diameter which have exhibited surface accuracies high enough to provide high gain communication links to 10GHz, and higher in certain cases, while manufacturing costs can be 10-20X smaller than equivalent mechanical systems. Much work has already been done on addressing most systems issues with good results. This technology is ready for a first flight.

Synthetic Aperture Radars (SAR):
L'Garde has built an inflatably deployed and supported SAR with surface planarity within +/- 15 mils. The Inflatable structure is rigidized and the technology is ready for a protoflight unit.

Solar Arrays:
Inflatably deployed and supported solar arrays, with subsequent rigidization of the inflatable structure, have been built and tested, yielding power densities 2X greater than the state of the art. Scale-up point designs have been conducted showing that the technology can reach into the neighborhood of 200 w/ kg. This technology is also ready for its first flight and L'Garde has a NASA SBIR towards this objective.

Booms:
Inflatable-rigidizable tubes and trusses have been built and tested showing high strength to weight ratios with low packaged volumes and controlled deployment.

INSTRUMENT TECHNOLOGIES AND ARCHITECTURES TECHNOLOGIES

- K CRYOCOOLER

Technology will provide cooling at temperatures as low as 4 K without producing any vibration. The advantage of this technology, relative to other cooling approaches, is that both very low temperatures can be achieved and coolers scale linearly down to very low capacity coolers, without losing efficiency. As a result, very low input power, low mass and long life coolers can be produced. This system enables the elimination of dewars and expendable cryogens from space missions, thereby significantly reducing mission cost and mass. Technology is proposed as part of the Integrated Cryogenic TeraHertz Spectrometers effort.

- CMOS ACTIVE PIXEL SENSORS (APS)*

CMOS Active Pixel Sensor Technology will provide: imager-on-a-chip cameras and autonomous, radiation-hard star tracker focal-plane arrays; smart, radiation-hard, high bandwidth optical communication FPAs; particle detectors and spectrometers-on-a-chip sensors.
Mission critical benefits of this technology include: ultra-low power (100s of microwatts); miniaturized (on-chip signal chain and >10bit ADC allow >10X reduction is mass of system); low-cost (fabricated using standard CMOS process); potential of imaging performance comparable to CCDs; radiation hard; x-y addressable array for multiple imaging modes.

- FLAT PANEL RADIATIVE COOLER

The FPRC is a new low cost modular design within the family of multi-stage passive radiative coolers that have been built at Raytheon SBRS over the last 25years. Prior to the FPRC development, our radiative coolers were round in shape, having been originally developed for spinning spacecraft in geosynchronous Earth orbit. Adaptations of the round coolers have flown on many LEO spacecraft and two planetary spacecraft, but they do not operate at peak efficiency due to the non-ideal proportions of the cooling radiator areas. Also, the round coolers were designed to contain an internal FPA, which made each cooler project-unique, with attendant high NRE costs. The FPRC is a 3-stage radiative cooler that uses the same materials and finish technology as the previous SBRS coolers, but with a square or rectangular frontal shape. The FPRC does not contain the FPA. Instead, the cold stage of the cooler is connected to a remotely located FPA through a flexible thermal link.

- HIGH PRECISION POINTING AND STABILIZATION MIRRORS AND DRIVES

Technology combines normally separate functions of large field-of-regard (FOR) pointing and ultra-high resolution/jitter control into one very lightweight, compact, low power, fast response Pointing/Stabilization Mirror Assembly (PSMA). The PSMA significantly reduces the cost of sophisticated EO imaging satellite systems and permits piggyback sensors to be placed on a proliferation of non-EO satellite platforms (i.e., communication satellites, platforms for landers and penetrators). The PSMA offers: (1) vastly improved (10x) precision pointing and stabilization performance (< 0.5rad) over large FOR (>"30 deg. sq.) under space environments; (2) a lightweight, very compact, low power design, when compared to conventional gimbaled mirror or sensor approaches; (3) significantly reduced (10x) satellite pointing requirements which lower overall cost and complexity; (4) reduced complex, expensive and often corrupted IMC processing; and (5) an enabling technology for autonomous, agile piggyback sensors on NASA, DoD and commercial non-EO host satellite platforms.

- HOT ELECTRON BOLOMETER HETERODYNE RECEIVER

This technology provides an alternative to SIS tunnel junctions and Schottky diodes for frequencies above 1 THz is a mixer based on a novel superconductive hot-electron bolometer (HEB) which uses diffusion as a cooling mechanism for the hot electrons. The bolometer mixer consists of a thin film micro-bridge of superconductor with normal metal pads at each end which serve as thermal heat sinks. The small heat capacity, due to the submicron size, and the high thermal conductance due to electron diffusion cooling lead to very fast response times: a few 10's of picoseconds are obtained for a Nb micro-bridge with submicron dimensions. This is several orders of magnitude faster than other conventional thin film or bulk bolometers.

- INP MMIC RADIOMETER TECHNOLOGY

InP High Electron Mobility Transistor (HEMT) technology has revolutionized millimeter-wave receivers for radiometer observational instruments and telecommunications. InP HEMTs provide high signal gain with low added noise, while consuming reduced power over previous transistor technologies.The ability to fabricate transistor amplifiers using monolithic millimeter-wave integrated circuit (MMIC) technology will enable the fabrication of complete radiometer systems "on a chip". This technique allows the utilization of amplifier technologies at frequencies as high as 200 GHz. For radiometer systems, the advantages of InP MMIC technology include reduced power, improved noise performance, size reduction over waveguide components, simplified integration in small packages, and operation at higher frequencies, reducing the size of required optical elements in many observational systems.

- INTEGRATED DUAL IMAGING DETECTOR (IDID)

The traditional approach to polarization measurements is to mount a rotating polaroid in the beam of a telescope. The IDID technology enables the achievement of a compact polarization stage with a mass of a few grams and no moving parts. The IDID provides simultaneous measurement of both orthogonal components of linearly-polarized light. Light is split by a birefringent crystal mounted between a microlens array and a CCD.

- PHOTOMIXER LOCAL OSCILLATORS

The photomixer is a compact solid-state source of continuous-wave THz power. It uses two tunable single-frequency diode lasers to generate a THz difference frequency by photoconductive mixing in low-temperature-grown (LTG) GaAs. The planar LTG-GaAs photoconductor couples very naturally to planar antennas, acting like a current generator with very wide instantaneous bandwidth. The photomixer is an evolving technology used, to date, primarily in laboratory-research systems. Present photomixers, however, are within reach of an important NASA application--widely tunable local oscillators (0.3-2.7 THz) that can pump heterodyne receivers based on superconducting mixers (SIS and hot-electron bolometers).

- PHOTON COUNTING OPTICAL RECEIVER

High sensitivity photon counting optical receivers are required for Earth and planetary laser remote sensing science missions. Specific requirements for these include receiver optical bandpass of 3-30 pm, photon counting rates from 1 to 300 Mcounts/s, pulse to pulse dynamic range of >10^5, photon counting sensitivity at wavelengths from 280 - 1064 nm, 0.1-5.0 degree field of view.

Two components are being developed: (1) tunable narrow band optical filters and (2) photon counting optical detectors. The innovations for the optical filters are the use of volume holograms (using PTR glass and polymers) and tunable etalons (using Cleartran). The innovation for the photon counting detectors is gallium arsenide photocathodes and a hybrid photomultiplier architecture that uses electron bombardment and avalanche diode anodes to achieve photoelectron gain. In addition, silicon avalanche photodiodes with enhanced near infrared sensitivity using reflective coatings and etalon cavities are being developed.

- SILICON CARBIDE OPTICS*

Silicon carbide offers the advantage of very high stiffness to density ratio and very high conductivity to heat capacity ratio. These characteristics are superior to currently used materials for reflective optical systems. The high stiffness to density ratio allows mirrors of very low weight to be designed and still maintain the necessary surface figure to provide the performance required for high-resolution optical imaging. Light-weight optics lead to light weight optical metering structures required to support them. This in turn leads to lighter instruments and therefore lighter payloads. Currently, only beryllium can compete with SiC for the lowest mass for a given optic size. SiC has the additional advantage of high thermal conductivity with relatively low thermal heat capacity. This property allows minimum thermal gradients for a given heat load. This is an advantage for an optical system in a low Earth orbit that experiences changes in thermal boundary conditions on a regular basis. SiC performs without competition in this arena. This leads to an optimum optical system design of SiC optics with a SiC optical metering structure. Using the high stiffness to weight ratio, a very low weight optical system can be constructed.

- SPATIAL HETERODYNE SPECTROSCOPY (SHS)

SHS offers capabilities for obtaining spectra of high spectral and spatial resolution, while achieving dramatic economies in size, cost, and ease of deployment compared to more conventional systems. The current SHS focus is a miniaturized instrument with the specific goal of measuring the global distribution of OH and NO in the Martian atmosphere. SHS is a relatively new and undeveloped spectroscopic method. It is a relative of Fourier Transform Spectroscopy (FTS), but has fundamental advantages over FTS in certain applications. In the SHS instrument, diffraction gratings replace the flat mirrors used in each arm of a conventional Michelson, and an imaging detector is used at the output to record a spatially heterodyned interferogram without any scanning elements. The mechanical simplicity of a diffraction grating is combined with the high light-gathering power of interference spectrometers. SHS systems can achieve an additional light-gathering gain of about a factor of 150 over conventional FTS or Fabry-Perot interference spectrometers by field-widening using fixed transmitting wedges. Flatness defects in the optics can largely be corrected in software, leading to relaxed tolerances that simplify extension to short wavelengths.

- PHOTOREFRACTIVE FILTERS

Lightweight, compact and tuneable filter and beam forming optical element. Aims to provide similar functionality to a holographic filter wherein multiple bandpasses can be superposed onto a single photorefractive crystal. By applying a spherical wavefront, it will be possible to focus a beam, combining a filter and mirror into one element. Use of a photorefractive material such as Lithium Niobate offers the ability to erase and tune, along with good mechanical stability and a relatively wide field of view.

- SURFACE PLASMON TUNABLE FILTER (SPTF)

SPTF is a new technology invented at JPL. It employs photon/electron interaction at metal/dielectric interface to select a spectrum. SPTF has advantages as: light weight (< 200 g), low power (<100 mw), wide temperature range (77~500 K), and covers the wavelengths from visible to IR beyond 10 micron. SPTF can be integrated with a solid state image sensor to build a miniature spectrometer. SPTF will enable visible and IR imaging spectrometer instruments that are: low power; low mass; miniaturized (spectrometer-on-a-chip); and low cost.

- COHERENT DOPPLER WIND LIDAR*

The long term goal is to enable profiling of horizontal wind speed in the troposphere. The instrument uses Doppler analysis of coherently detected backscatter from entrained aerosols and cloud particles in the troposphere to measure wind velocity. The solid state transmit laser produces a 0.5J energy/0.5μs long single mode pulse at a wavelength of ~2μm. The transmitted beam is expanded to a collimated beam by a 0.5m diameter nadir looking telescope and deflected 30 deg. from nadir by a rotating optical element to form a conical scan pattern. Prior designs for coherent Doppler lidars for measuring winds from space used large multi-joule gas lasers combined with large diameter (>1.5m) telescopes. The resultant lidar system required ~3kW of power, had a mass ~800kg and a cost of ~$0.5 billion. Through the use of lighter, more efficient solid-state lasers, the elimination of the need for detector cryo-coolers and the adoption of more compact telescope geometries this instrument consumes <500W, and has a mass <400kg.

- FOURIER TRANSFORM SPECTROMETER SOUNDING (FTS)

The FTS technologies enable affordable, advanced atmospheric temperature, chemical composition, cloud, and surface observing for weather and climate. High vertical resolution temperature and water vapor soundings for improved weather forecasts. Trace gas vertical profiles for climate monitoring and modeling. The advanced technologies in support of a new generation FTS are: stable laser: dynamic optical alignment and metrology; optical path difference scan mechanism; onboard scientific feature extraction; and high efficiency mechanical coolers.

- GEO-GLOBAL TROPOSPHERIC EXPERIMENT

High specificity, high spatial and temporal resolution, 2-D imaging of trace gases such as CO and CH4 from geostationary Earth orbit. Gas Filter Correlation Radiometry combined technologies for mid-IR focal plane array imaging cameras, high accuracy pointing system and filter wheel for gas cells. IR detectors are radiation hard HCT large format (512^2 and 1024^2 pixel) focal-planes with near BLIP sensitivities. Incorporates advanced radiative cooler technology.

- HIGH RESOLUTION LINEAR VARIABLE ETALON SPECTROMETER

HRLVE technology enables a high spectral resolution, infrared solid-state spectrometer for determination of atmospheric structure and composition, from the upper troposphere to the mid-stratosphere. High resolution enables accurate measurement of weak spectral features in the presence of strong interfering molecular line emitters, and in the presence of high quasi-continuum backgrounds from sulfate aerosols and PSCs. Operating in emission enables high geographical measurement density and coverage throughout the diurnal cycle, including measurement inside the polar night vortices.

These aspects of the HRLVE technology are directed to the need to map the global distributions and monitor the seasonal variability and longer-term trends of tropospheric source gases, aerosols, and clouds, as well as gases of stratospheric origin, in the troposphere-stratosphere exchange region, and in the tropical to higher latitude exchange region in the low to mid stratosphere.

The technology involves the coupling of a high resolution linear variable wedged solid Fabry-Perot etalon with a 2-D cooled detector array, to provide simultaneous wavelength scanning and spatial coverage without the use of mechanisms. This enables large reduction in mass, size, and complexity, and sensible improvement in long-term reliability vs conventional, similar-performance instruments.

- TROPOSPHERIC OZONE FABRY-PEROT INTERFEROMETER

NADIR emission viewing Fabry-Perot Interferometer for tropospheric (and total) ozone observations. Component technologies and subsystem implementation are also applicable to additional tropospheric trace species measurements. This technology will be enabled through the advancement of the following component technologies:
High performance LWIR linear focal-plane arrays with high sensitivity at warmer temperatures than current 10micron detectors.

FPI fringe concentration converter to enable detection of entire fringe patterns using linear arrays of reduced area. An additional signal gain will be realized by allowing a multi-channel configuration, whereby all necessary frequencies can be measured simultaneously.

Etalon mounting and control to improve defect finesse and a priori knowledge of its value ensure proper optical coatings for maximizing throughput in any FPI system.

- DIRECT DETECTION DOPPLER WIND LIDAR

Direct Detection Doppler Lidar technology is used to detect global tropospheric wind speed and direction. Direct detection refers to the detection process in which the measured quantity is the light intensity rather than its phase as in coherent detection. The technologies employed for direct detection Doppler lidar are closely related to the lidar technologies already successfully demonstrated in space on LITE, MOLA, and SLA and which are being developed for GLAS and Vegatation Canopy Lidar (VCL). The innovation will be to build on this technology base to produce a lidar capable of measuring winds from space.

The direct detection Doppler lidar approach can be utilized to make wind measurements by measuring the Doppler shift using back-scatter from either aerosols or molecules.
Because the aerosol return remains spectrally narrow a high sensitivity velocity measurement can be obtained with a lidar operating at a wavelength of 1064 nm. The molecular back-scattered signal is spectrally broadened due to the random thermal motion of the molecules. The resulting measurement sensitivity will be lower than the aerosol system. This loss of sensitivity can be partially offset by operating at 355 nm where the molecular back-scatter will be large. The molecular system has the added advantage that the back-scattered signal will be uniform and predictable globally while the aerosol back-scatter is highly variable and in some places may be undetectable. An optimum system would combine an aerosol measurement at 1064nm with a molecular measurement at 355 nm using a common transmitter

The instrument utilizes a Nd:YAG laser operating at 1064nm, capacitance stabilized tunable Fabry-Perot etalon filter, large aperture (1 m) telescope, and photon counting Si APD detectors. The laser pulse is transmitted to the atmosphere with a nominal nadir angle of 45 degrees. A large aperture telescope collects that portion of the signal that is back-scattered by atmospheric aerosols and molecules. The return signal is processed through the high spectral resolution etalon filter using the edge technique to measure the Doppler shift. Wind measurements are made with the edge technique by locating the laser frequency on the steep edge of the transmission function of a high spectral resolution optical filter. Due to the steep slope of the edge, small frequency shifts cause large changes in measured signal. A recent innovation, the double edge technique, utilizes the same principle but with two identical etalon filters with bandpasses which have been shifted such that the Doppler shift is measured on the negative slope of one filter and simultaneously on the positive slope of the second filter. This produces twice the change in measured signal for a given Doppler shift.

- INTEGRATED CRYOGENIC TERAHERTZ SPECTROMETER

The ICTS is an integrated heterodyne receiver operational from 1 to 3 THz, one of the largely unexplored regions of the electromagnetic spectrum. Science goals in this spectral regime include astrophysical line emission studies and atmospheric constituent emission studies for earth remote sensing and planetary exploration.

The sub-system consists of a hot electron bolometer (HEB) mixer, photo-mixer tunable LO source, cooled InP HEMT IF amplifier and a digital autocorrelation spectrometer. The maximum noise temperature for the system is 10,000 K (DSB), which can be achieved with a high Tc HEB mixer. However, the noise is expected to be lower for a low-Tc HEB mixer. A digital autocorrelation spectrometer with 2 GHz of bandwidth can be fabricated with a resolution as high as 1 MHz. The instrument requires cryocoolers to cool the HEB to superconducting temperatures.To demonstrate the full suite of technologies required for sensitive (2000 K noise) submillimeter spectroscopy, the instrument must be cooled to 4 K. This requires The power consumption of the receiver will be between 100 and 160 Watts depending upon the configuration with corresponding mass between 100 and 150 kg.

- SILICON CARBIDE OPTICS AND COMPOSITE METERING STRUCTURE

The proposed technology is a SiC optical system that combines castable, monolithic SiC mirrors with composite SiC structures to create a light-weight, passively athermal cryogenic optical system for Earth remote sensing or planetary missions. SiC is widely recognized as a light-weight, high performance mirror material. The key innovation proposed here is to combine monolithic SiC mirrors with a composite SiC structure. The matching CTE's of the like-materials enable passive athermal performance to cryogenic temperatures, and the fracture tough composite SiC enables light-weight design and eliminates any brittleness concerns associated with monolithic SiC structures.

- MICRO-CRYOCOOLERS

The development of micro-cryocooler technology will enhance space-based science gathering capabilities across many disciplines. This technology enables significantly smaller cryo-cooled instruments and spacecraft communications. Micro-cryocoolers with their exceptionally long life will reduce mission costs due to reduction in instrument system mass, replacement of heavy expendable cryogen systems and extension of mission duration. These micro-cryocoolers reach 30K with a cooler mass of 400 gms, as compared to 13 kg mass of conventional mechanical coolers.

- WIDE-FIELD IMAGING SPECTROMETER (WFIS)

This instrument approach will make possible MODIS capability with an order of magnitude reduction in instrument cost, mass, size and power. Implementation of the technologies contained in the WFIS will enable ultra-wide (120^o) entrance optics for pushbroom imaging. Longer signal integration times allow reduced instrument size for imaging spectrometers. The WFIS also enables separate small spectrometers for each focal plane technology, thereby permitting flights on the same or separate platforms. The key technologies in this instrument are the ultra-wide field of view (FOV) optics, wide FOV imaging spectrometer, silicon imaging area array detectors and infrared imaging array detectors.

- GAS AND AEROSOL MONITORING SENSORCRAFT (GAMS)

The GAMS system concept provides global, daily coverage with a constellation of small, but highly capable, autonomous sensorcraft launched as secondary payloads. The key sensorcraft parameters are: mass; 60 kg, power; 75 W average and volume; 0.1 m3. GAMS is being designed in the tradition of the SAM and SAGE instruments to use solar occultation to provide profiles of the Earth's atmosphere. The key instrument parameters are: grating spectrometer with spectral coverage; 720 to 970 nm, aperture; 5 mm, field of view; 1.7 arc min, profiling region; 5 to 40 Km, and resolution; >1 Km. GAMS makes profile measurements of ozone, aerosol, water vapor, pressure, and temperature. GAMS instrument and sensor technology includes high resolution, deep-well (20 million e^-) CCD detectors, on-board data processing and a "smart", radiation-hard controller. The sensorcraft technologies also include piezo-electric motors (THUNDER), a carbon-carbon optical structure and multi-functional structures.

- MINIATURE WEDGE IMAGING SPECTROMETER (Mini-WIS)

The mini-WIS is based on a novel patented concept wherein a linear variable spectral filter (wedge filter) is mated directly to an area detector array to form a compact detective assembly that performs the dual functions of spectral dispersion and imaging. This compact assembly avoids the use of complex aft optics required by imaging spectrometers based on gratings or prisms. The WIS is a thin-film optical device that transmits light in a band with center wavelength a linear function of distance along the length of the filter. When an array of detectors is placed behind the wedge filter, each line of detectors receives light from the scene at a different center wavelength. Hence, the array output is a sampled spectrum of the scene. The detected scene information from a single frame will vary spectrally in one direction and spatially in two directions. An imaging spectrometer results which this detective assembly is scanned across a scene along the axis of spectral variation. Recording a series of frame images during this scan builds a complete two-dimensional spatial image in each of the detected spectral bands

*** Identifies those technologies that have been manifested on an approved New Millennium technology validation flight.**

APPENDIX H

Implementation Approach

The following implementation and mission operations approach is provided for information only.

At the completion of the mission concept definition phase the resultant deliverables will be subjected to an independent peer review. The proposals will be ranked and one will be selected by the AA OES for follow on implementation. In addition, one other concept will be selected as a backup at a low level of sustaining funding. The selected mission will be assigned to a NASA center or JPL for implementation. The assigned center will appoint a project manager and will competitively select the spacecraft bus provider. The center will arrange for transportation to space. The provider for the instrument and other technologies to be validated may be competitively selected or the implementation could be assigned to the instrument providers institution, or delegated to a NASA center or other government laboratory. The selected organizations will work in a teaming mode with the first major milestone being a confirmation review, generally about six months into the mission refinement phase. If the mission fails the confirmation review the backup mission will be activated. If the confirmation review is successful then the backup mission will be canceled with no guarantees from NASA that it has a preferential place in an subsequent acquisition action. In addition, other advanced technologies selected for validation on the mission that are not already represented on the NMP IPDTs, will require a focused competitive procurement at the start of mission refinement and implementation phase.

A separate AO process will be used to select scientists to participate in the development of science objectives and participate as members of the science validation team during mission operations. The exact mode of mission operations will be determined as a result of trade studies accomplished in the mission definition phase.

APPENDIX I
ACRONYM LIST

Active Pixel Sensor	APS
Advanced Microcontroller	AMC
Advanced Multi-Mission Operation System	AMMOS
Announcement of Opportunity	AO
Architecture Development Team	ADT
Deep Space Communications Complex	DSCC
Deep Space	DS
Earth Orbiting	EO
Envelope Learning and Monitoring using Error Relaxation	ELMER
Facilities and Administrative	F&A
Field of Regard	FOR
Fourier Transform Spectroscopy	FTS
Geosynchronous Earth Orbit	GEO
Goddard Space Flight Center	GFSC
Graphical User Interface	GUI
High Performance Data Compression	HPDC
High Resolution Linear Variable Etalon	HRLVE
Hot-electron Bolometer	HEB
High Electron Mobility Transistor	HEMT
Instrument Incubator Program	IIP
Integrated Cryogenic Terahertz Spectrometer	ICTS
Integrated Dual Imaging Detector	IDID
Integrated Product Development Team	IPDT
Jet Propulsion Laboratory	JPL
Lithium-ion	Li-ion
Long Duration Environment Facility	LDEF
Low Temperature Grown	LTG
Monolithic Millimeter-wave Integrated Circuit	MMIC
Multichip-Module	MCM
Multifunctional Structures	MFS
NASA Research Announcement	NRA
National Aeronautics and Space Administration	NASA
New Millennium Program	NMP
Nickel-Cadmium	Ni-Cd
Nickel-Hydrogen	Ni-H2
Office of Earth Science	OES
Office of Space Science	OSS
Optical Communications Demonstrator	OCD
Personal Computer Memory Card International Association	PCMCIA
Pointing/Stabilization Mirror Assembly	PSMA
Principal Investigator	PI

Pulsed Plasma Thruster	PPT
Reed-Muller	RM
Reed-Solomon	RS
Silicon Carbide	SiC
Spatial Heterodyne Spectroscopy	SHS
Surface Plasmon Tunable Filter	SPTF
Synthetic Aperture Radars	SAR
World Wide Web	WWW